

Emerging Milk Protein Opportunities

The latest research on applications, processing and markets



DMI DAIRY MANAGEMENT INC.™

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Market Opportunities for New-Generation Dairy Ingredients

Milk is a rich source of nutrients that can be fractionated into a wide range of components and used as ingredients to boost the protein value of foods and beverages. Next-generation dairy ingredients gaining attention are whey proteins isolated directly from milk. Research indicates that these whey proteins have both similar and different attributes as traditional whey proteins isolated from cheese whey.

Due to their nutritional and functional benefits, whey protein ingredients expand the possibilities to formulate protein-packed foods and beverages that consumers demand.

Health and wellness

Protein plays many important roles, such as repairing the body's cells; building and repairing muscles; helping build and maintain bones; and helping control many metabolic processes.

Food and beverage manufacturers are boosting the protein content of products to tap into the growing health and wellness trend. According to a 2009 Mintel survey, 86 percent of respondents indicated that eating healthy is very or somewhat important to them.¹

Currently, many food and beverage manufacturers use whey proteins as the protein source of choice for product innovation. According to Mintel, 4,100 new food and beverage products containing whey protein ingredients were introduced to the U.S. retail market from 2003 to 2009.² These products include nutrition and energy bars, ready-to-drink beverages, smoothies, beverage mixes, meal replacements, cereal and yogurt.



Feeling full and managing weight

One benefit to protein-rich products is their satiety effect. A higher protein diet can help people feel fuller longer, which may help eliminate the desire to reach for unhealthy snacks between meals. "Consuming more foods with added whey protein is a simple way to increase protein intake and help achieve a higher protein diet for satiety benefits," says Matt Pikosky, Ph.D., R.D., FACN, director of research transfer at Dairy Management Inc.™ (DMI).

According to a 2008 survey conducted by NPD Group for DMI, 67 percent of consumers stated that feeling full is important when trying to lose weight and two-thirds believe that satiety is important in their food and beverage choices.³ Research continues to uncover the role whey protein plays in satiety benefits to help consumers manage their weight and avoid between-meal snacking. *(continued on Page 8)*

Global Demand for Dairy Protein on the Rise

Worldwide, protein consumption is increasing, and there are multiple reasons for this increase.

As economies create wealth, there is an increased consumption of animal protein, including dairy, which is a higher-quality protein than many plant-based protein sources. In developing countries, protein is used to improve basic nutritional quality for its citizens. These countries use whey proteins for applications such as infant formula, canned milk, dairy products and baked goods.

Developed countries seek protein to improve health, wellness and performance. "These countries are looking for foods that can deliver specific health benefits," says Phil Tong, Ph.D., director of the Dairy Products Technology Center at California Polytechnic State University in San Luis Obispo, Calif. "As a result, the functional food segment of health and wellness foods has been steadily increasing over the past few years, and whey protein has become a choice ingredient for those products."

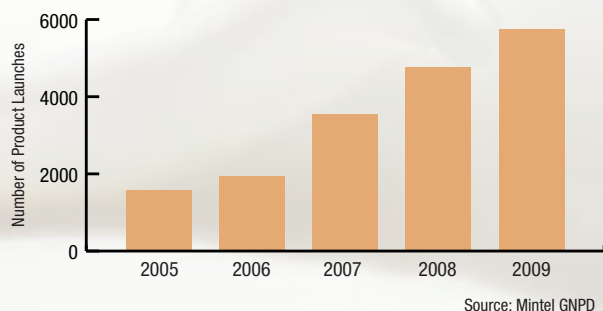
According to Mintel International, functional food and beverage product introductions worldwide grew from 1,566 products in 2005 to 5,753 products in 2009.

More mouths to feed

Population growth worldwide also is a factor in increased protein demand. In many countries, the population is growing faster than its own dairy production can handle for the immediate future, requiring them to find international sources for dairy protein.

Plus, the growing middle class worldwide will continue to be a factor in the rising demand for protein. There will be an estimated additional 800 million middle-class consumers worldwide by 2030, the majority of that growth coming from China, India and Southeast Asia,⁷ according to research conducted by Bain & Company on behalf of the Innovation Center for U.S. Dairy, which is supported and staffed by Dairy Management Inc.™

FUNCTIONAL FOOD & BEVERAGE INTRODUCTIONS WORLDWIDE



⁷Bain & Company, Dairy Globalization – Threats, Opportunities and Implications, 2009. Research conducted in association with the Innovation Center for U.S. Dairy's Globalization Task Force.

The growing middle class worldwide will continue to be a factor in the rising demand for protein.

"As countries continue to grow and look for ways to improve the overall health of their citizens, we can expect their demand for whey protein to increase as well," says Vikki J. Nicholson, vice president of U.S. Manufacturing and Ingredients Marketing at the U.S. Dairy Export Council. "The United States has a great opportunity to provide a significant portion of the global whey protein supply." ■

Products That Perform: Milk Fractions Help Manufacturers Develop Higher-Protein Foods

Bland flavor and aroma, excellent foaming characteristics and low turbidity are just some of the benefits of whey proteins derived directly from milk, appealing to makers of protein-enhanced food and beverage products, according to researchers at the Wisconsin Center for Dairy Research (WCDR), located at the University of Wisconsin-Madison.

"Whey proteins derived directly from milk are new-generation dairy ingredients that hold great potential for foods and beverages formulated with high concentrations of protein," says K.J. Burrington, coordinator of the Dairy Ingredients Applications Laboratory at the WCDR. "Promising applications include sports and nutritional bars and beverages, baked goods, whipped confectionery items and snack foods."

The key attributes of whey proteins derived directly from milk come from the nature of the production process. The end product is more consistent because it has not undergone the cheesemaking process, which inherently adds certain variables, such as differing cheese types, rennet enzyme, colors and starter cultures. In addition, the process of fractionating whey proteins directly from milk requires fewer heat pasteurization steps, which reduces protein denaturation and preserves product solubility.





The whey proteins derived directly from milk also contain less than 1 percent fat, even when concentrated to as high as 80 percent protein. That accounts for their bland flavor, low turbidity in solution, foaming capability and stability during storage.

“Being low in milkfat and phospholipids, whey proteins isolated directly from milk have low susceptibility to oxidation,” notes John Lucey, Ph.D., professor of food science at the University of Wisconsin-Madison and researcher at the WCDR. “Therefore its flavor tends to remain consistent even after prolonged storage.”

Value-added ingredient

Whey proteins derived directly from milk serve well as a high-value-added ingredient for products that have nutritional targets. The highest-potential applications are for products in which whey protein is added for nutritional fortification of functional foods (6 percent to 7 percent protein). Substantial amounts of these whey proteins can be added with minimal effect on flavor, aroma and appearance.

Benefits for beverages

Burrington considers beverages a very promising application because consumers are especially sensitive to flavor and aroma in drinks. “In more highly flavored items like cookies and energy bars, the mild dairy flavor in whey proteins isolated from cheese whey usually complements the taste,” she says.

“On the other hand, in beverages, bland flavor in a protein concentrate is a positive attribute,” Burrington says. “Sensory research indicates that consumers readily detect unwanted flavors and aromas that they do not expect in a beverage.”

Furthermore, with low turbidity and high solubility, whey proteins derived directly from milk can be added to clear beverages – like sports drinks, flavored waters, vitamin waters and some juices – with little or no effect on their appearance.



Expanding functional foods

As consumers continue to look for nutritionally enhanced food options, manufacturers can find opportunities to add protein to a wider array of foods. The bland flavor profile of whey proteins derived directly from milk also would work well as a protein-enhancer in mild-flavored foods such as yogurts, flavored milks, smoothies, white sauces and some soups.

Breaking away from eggs

The foaming properties of whey proteins derived directly from milk also create potential for baked goods and whipped products that traditionally rely on eggs for foaming and whipping.

“Egg is currently the dominant ingredient for those applications, but whey proteins derived directly from milk are viable partial replacements for egg in many applications,” Lucey says.

Choosing the right whey protein

Whey proteins isolated directly from milk are not necessary for all applications. While they are suitable ingredients for products like cereals and snack bars, whey proteins isolated from cheese whey already serve those applications well, Burrington says. In baked goods, some whey proteins isolated from cheese whey impart a slight dairy flavor that enables other flavors, such as chocolate, to develop to their full potential. In sourdough bread, the distinctive flavor of acid whey has been used to enhance the flavor contributed by fermentation.

“Whey proteins derived directly from milk are part of a new generation of dairy ingredients,” Burrington says. “Yet, whey proteins isolated from cheese whey will always play an important role in formulating many foods and beverages. There is still room for innovative ingredients that can help manufacturers develop enhanced products and drive further dairy ingredient usage.” These new ingredients are particularly important as the food industry tries to add higher levels of protein to their products. ■



Research Opportunities Applications

Now High-Protein Products can Taste Better

Whey proteins derived directly from milk rather than from cheesemaking have potential to give food processors more options in creating and improving the flavor of high-protein products.

Ongoing research has found that these milk protein fractions have flavor properties that are distinct from those of whey proteins isolated from cheese whey, according to MaryAnne Drake, Ph.D., professor at North Carolina State University (Raleigh) and director of the Sensory Applications Laboratory that conducted the studies.

In particular, whey proteins isolated directly from milk are lower in fat and more bland in flavor at neutral pH than commercial whey proteins. "This essentially gives food manufacturers a new tool in the dairy ingredients toolbox," Drake says. "We now have a dairy ingredient with a distinct flavor profile that is very well suited for protein-enhanced foods."

In studies conducted at North Carolina State University, researchers compared the flavor chemistry and sensory properties of whey protein concentrates (WPCs) derived directly from milk with commercial WPCs from a variety of sources.

Studies examined both 34 percent protein and 80 percent protein concentrates. Sensory analysis was conducted by trained sensory panels using concentrates rehydrated at 10 percent solids, as well as trained sensory panel and consumer acceptance testing using an acidified (pH 3.5) peach beverage containing 6 percent protein. The appearance liking of the beverage containing the WPC derived directly from milk was the best liked overall by panelists for its superior clarity.

The WPC produced in the lab was more bland in flavor and lower in lipid oxidation products than commercial WPCs of similar composition. Plus, there were inconsistencies in flavor characteristics among the commercial products.

"The sensory characteristics of whey proteins isolated directly from milk can be particularly beneficial for applications such as neutral pH meal replacement beverages with flavors like vanilla," Drake notes. "With a bland-flavored WPC, processors could add large

amounts of protein without the need to add masking ingredients to cover up undesirable flavors."

Sensory research on whey proteins derived directly from milk will continue to reveal best applications for new product innovations.

"Understanding flavor, flavor formation and consumer perception are key for determining what kind of whey protein is best for a particular formulation," Drake concludes. ■

Membrane Options Create new Protein Opportunities

Research on microfiltration is working toward helping dairy processors efficiently isolate soluble proteins directly from milk. The microfiltration process can produce isolated soluble proteins directly from milk that have different functionality and protein composition when compared with whey proteins derived from cheese whey.

Different membranes, unique benefits

There are different types of microfiltration membrane systems available to dairy processors in manufacturing protein ingredients, according to David Barbano, Ph.D., professor of food science at Cornell University. Over the last several years, Barbano has extensively researched ultrafiltration and microfiltration of milk but says there are two membranes most commonly used by today's dairy processor.

"The differences and benefits between these membranes really have to be netted out by the processor, depending on their goals and applications for the product," Barbano says.

Ceramic. A ceramic membrane has a nominal pore size of 0.1 micron and is more tubular in shape. It provides numerous benefits, including high-heat tolerance and quicker clean-up and flushing after processing. The cost to operate, however, is higher than using a polymeric membrane.

“We now have a dairy ingredient with a distinct flavor profile that is very well suited for protein-enhanced foods.”

- MaryAnne Drake, Ph.D., director of the Sensory Applications Laboratory



Polymeric. The spiral-wound polymeric membrane pore size is wider at 0.3 micron. While more energy efficient and less costly to operate, its recovery of soluble proteins is very low. Also, spiral-wound membranes are more challenging to clean following processing, and the life of the membrane is shorter than that of a ceramic membrane.

Potential applications for these proteins isolated directly from skim milk include nutritional beverages, particularly shelf-stable retorted beverages when casein concentrate is used from this process.

“Microfiltration, in my opinion, will have a lasting impact and role in the dairy industry, much like we saw with centrifugal cream separation,” Barbano says. “I believe it will change the way we work in dairy processing plants.” ■

Enhanced Functionality for Protein-Packed Products

Whey proteins derived directly from milk can provide some highly desirable functional properties for many protein-packed foods and beverages.

E. Allen Foegeding, Ph.D., a William Neal Reynolds Distinguished Professor of food science at North Carolina State University (Raleigh), has been researching these functional properties at the Southeast Dairy Foods Research Center.

The research examined the functional properties of 34 percent and 80 percent concentrates of whey proteins isolated directly from milk and whey proteins isolated from cheese whey, using the same milk source from both. His research team found that whey proteins derived directly from milk are similar to the whey proteins isolated from cheese whey in their solubility and heat stability. However, they differ with respect to other important properties:

Clarity. Whey proteins isolated directly from milk had smaller particle sizes and therefore showed greater clarity when dissolved in water than those derived from cheese whey. “This makes

them especially beneficial in beverage applications where the manufacturer desires a clear appearance,” Foegeding says.

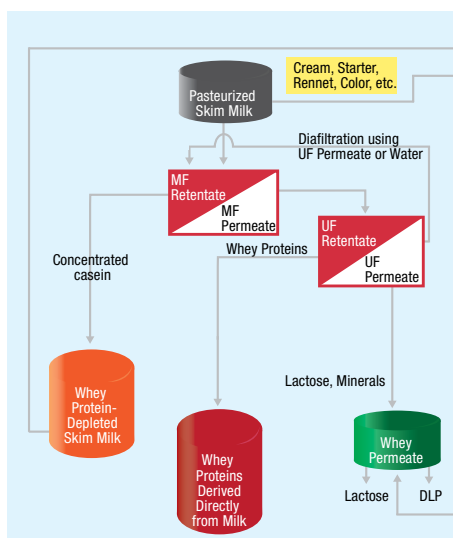
Foaming. Whey proteins derived directly from milk, being lower in fat, produced greater volumes of foam that was also stronger and longer-lasting. “This is important when using whey protein as a substitute for egg white, or when developing high-foaming ingredients,” Foegeding says.

Foaming also is valuable in confectionery products, where aeration is used to create a light texture, and in baked goods where foam stabilization is key to forming the desired structure.

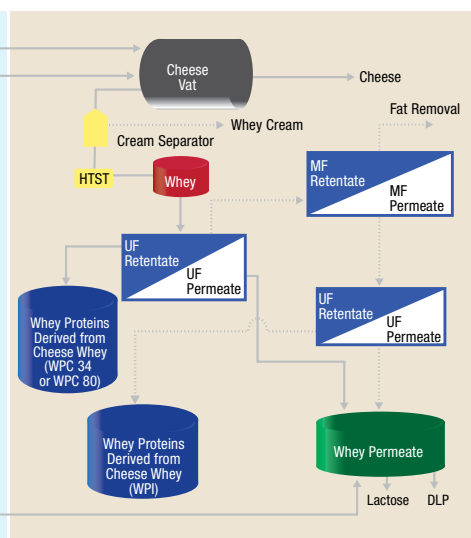
Gelation. Compared with whey proteins isolated from cheese whey, whey proteins isolated directly from milk formed a stronger gel network. This attribute can be beneficial in a variety of applications, such as providing structure to bakery products.

Producing whey protein ingredients derived directly from milk allows for enhancing specific functional properties, giving food and beverage manufacturers more choices and flexibility when creating protein-enhanced products that appeal to consumer preferences. ■

WHEY PROTEINS DERIVED DIRECTLY FROM MILK



WHEY PROTEINS DERIVED FROM CHEESE WHEY



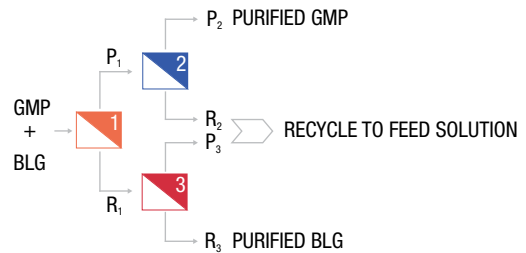
Fractionating With Charged UF Membranes

Historically, ultrafiltration (UF) has been used in the dairy industry to concentrate milk proteins. However, research indicates that when a charge is added to a UF membrane, existing UF equipment can be used to fractionate milk proteins. This means dairy ingredient manufacturers can increase the return on investment of their membrane systems by producing higher-value milk protein fractions.

Charged membranes are made by chemically treating commercially available UF membranes already in use by the dairy industry. The treatment places a permanent positive charge on the membrane that will not wash off and provides a stable boost to the separation power.

Mark Etzel, Ph.D., professor of food science at the University of Wisconsin-Madison, conducted research on how charged membranes impact milk protein fractionation. Three protein solutions were investigated in the test: glycomacropeptide (GMP), beta-lactoglobulin (BLG) and a binary mixture of both GMP and BLG. The efficacy of fractionation was determined at four levels of pH, ranging from 3.0 to 7.5, and filtration pressures ranging from 0.14 to 2.1 bar. Solutions with the same pH conditions were filtered using uncharged membranes to study the separation power of the charged membranes to fractionate GMP and BLG.

MILK PROTEIN FRACTIONATION USING CHARGED MEMBRANES



*R1, R2, R3 = retentate of UF membrane, Stages 1, 2 and 3, respectively
P1, P2, P3 = permeate of UF membrane, Stages 1, 2 and 3, respectively*

The research found that adding a positive charge to the ultrafiltration membrane increased the separation power by more than 600 percent. The GMP and BLG were successfully separated using the charged membrane, but not when using the uncharged membrane. Charged membranes cleanly fractionate similarly sized proteins from cheese whey, something that has not been feasible in the past.

An alternative to ion exchange

Additional research is under way to measure whether going through a series of membranes can increase the purity and yield of milk protein fractions derived directly from milk. The results to date are encouraging.

“For manufacture of milk protein fractions directly from milk, charged UF membranes may replace ion exchange resins in some applications,” Etzel notes. “This change in technology can lower the cost and improve simplicity of fractionating milk proteins.” ■

Process Innovation Offers Strong Market Potential With Beta-Casein

Innovations in microfiltration now enable dairy ingredient processors to extract three distinct ingredient streams from whole milk in a single, integrated process.

Research conducted at the Wisconsin Center for Dairy Research (WCDR), located at the University of Wisconsin-Madison, has resulted in a new process (patent applied for) that yields beta-casein concentrate, whey proteins and casein, directly from whole milk in a cold process.

The additional isolation of beta-casein provides a new revenue stream with strong market potential. In fact, according to the U.S. International Trade Commission, caseins represent about 30 percent of all dairy imports.

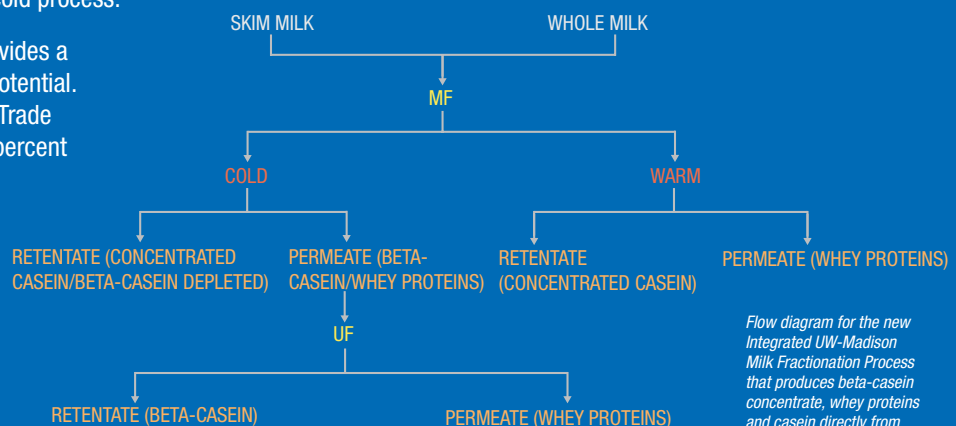
U.S.-produced beta-casein could take the place of imported sodium caseinate for applications that require foaming and emulsification properties. Infant formula manufacturers also have shown interest because beta-casein would enable them to create formulas that more closely

mimic human breast milk, which has a higher ratio of beta-casein to other caseins.

Advances in filtration

John Lucey, Ph.D., professor of food science at the University of Wisconsin-Madison, and Karen Smith, Ph.D., dairy processing technologist at the WCDR, report that new advances in microfiltration have greatly enhanced the commercial prospects for isolating the three streams from milk.

“Ceramic microfiltration membrane filtration systems have been used for certain specialized applications in the dairy industry,” Lucey says. “We now have polymeric membrane systems that



Flow diagram for the new Integrated UW-Madison Milk Fractionation Process that produces beta-casein concentrate, whey proteins and casein directly from whole or skim milk at cold or warm temperatures.



Membrane filtration equipment at the WCDR.

are simpler and much less costly to operate, providing ingredient processors options to fractionate milk.”

Keeping it cold

Lucey’s research team explored microfiltration of whole milk as a way to fractionate proteins. They found that even when filtered cold (at less than 7°C), whole milk compared favorably with skim milk in terms of membrane flux and permeate rates of whey proteins derived directly from milk, but without damaging the fat.

The integrated process they developed starts with microfiltration of cold whole milk to create beta-casein-reduced milk that could be used for cheese production or casein concentrates, and a permeate containing beta-casein and whey proteins derived directly from milk.

The permeate then goes through additional membrane filtration steps to produce two streams: one with whey proteins, the other with enriched beta-casein. The beta-casein fraction can be concentrated to produce a product with 80 percent beta-casein. Currently, there is no commercially available beta-casein product available. The beta-casein concentrate produced at the WCDR is free of the things that get added in the cheesemaking process (e.g., color, rennet or starter culture). The beta-casein concentrate has excellent foaming properties, emulsification and heat stability.

In further work, the researchers used raw whole milk for the fractionation process, which could be useful in the purification of heat-sensitive proteins.

“All process streams are highly functional – there are no waste products,” Lucey says. “This research points the way to generating more revenue by creating multiple value-added dairy ingredients from a single, integrated process.” ■

Enriched Protein Fractions via Supercritical Carbon Dioxide

Research indicates that when supercritical carbon dioxide is incorporated in the process of fractionating whey proteins directly from milk, the result is a viable method for isolating alpha-lactalbumin and beta-lactoglobulin ingredients. Supercritical carbon dioxide is pressurized carbon dioxide at temperatures greater than 31.1°C and pressures greater than 7.39 MPa.

These enriched fractions are ideal for use in sports drinks, snack bars, confectionary, encapsulation, bakery products and a variety of foods that support the health of the elderly. In addition, beta-lactoglobulin is valuable for its gelling properties in surimi-type products, puddings, and many health and wellness products.

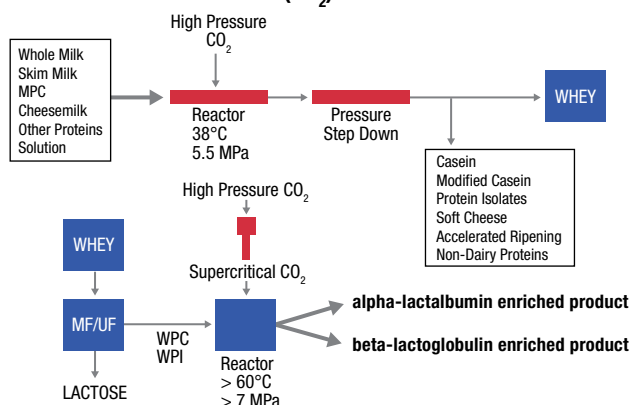
Unlike other methods to isolate these proteins, which included chemically based separation or reverse osmosis, the supercritical carbon dioxide method does not require solvents or leave a residue.

“This process eliminates the addition of chemicals to the whey, so it reduces the number of processing steps necessary to clean the products,” says Peggy Tomasula, research leader, and Laetitia Bonnaillie, researcher, both for the U.S. Department of Agriculture’s Agricultural Research Service - Eastern Regional Research Center. “In addition, the process uses less water — owing to a concentrated feed stream and no need for washing — and the carbon dioxide can be recovered and reused.”

How it works

In this process, whey protein isolate or whey protein concentrate is forced into a reactor simultaneously with the supercritical carbon dioxide charge. Under the right temperature and pressure in the reactor, alpha-lactalbumin aggregates and beta-lactoglobulin stays in solution, creating two ingredient streams.

INTEGRATED CARBON DIOXIDE (CO₂) MILK FRACTIONATION PROCESS



The future of supercritical carbon dioxide for fractionation

Researchers are continuing to study aggregation kinetics and modeling in order to maximize the efficacy of the protein separation, as well as minimize the time, energy and equipment costs incurred in the production of fractions using supercritical carbon dioxide. Future studies will look at optimizing the whey protein’s functionality and increasing carbon dioxide recovery. ■

Market Opportunities

(continued from Page 1)

Building muscle

Whey protein has been shown to have a positive effect on muscle recovery after exercise. For example, in a study using eight resistance-trained young men, the Exercise Metabolism Research Group with the Department of Kinesiology at McMaster University, Canada (part of the National Research Council in Canada), found that consuming a carbohydrate drink containing 10 grams of whey protein with 21 grams of fructose following resistance exercise led to a greater rise in muscle protein synthesis compared with a beverage containing an equal amount of carbohydrates only.⁴

Combating muscle wasting

Whey protein and resistance exercise can play an important role in combating sarcopenia, the age-related loss of muscle mass, function and strength that affects an estimated 30 percent of people over 60.⁵

Research has shown that routine resistance exercise and adequate amounts of dietary protein can prevent, reverse or slow the progression of this muscle loss to help aging consumers maintain an active lifestyle.⁶



Food and beverage manufacturers can leverage the quality and value of whey proteins in their product innovations to reach the mature consumer.

Additional research is under way to investigate the potential beneficial impact of whey protein on immune function, inflammation and blood pressure.

Unified research initiative

Due to the growing demand for protein ingredients and the increasing need to produce quality whey proteins, researchers are studying the opportunities to cost-effectively isolate whey proteins directly from milk. A coordinated effort sponsored by DMI has brought together research centers from across the United States to study the many facets of whey proteins isolated directly from milk and its production.

"This research initiative is continuing to uncover the functional and sensory benefits of whey proteins derived directly from milk, as well as a number of new milk protein fractionation processes that could have diverse applications in the dairy and food industries," says Bill Graves, senior vice president of product research at DMI. ■

¹ Attitudes Towards Food – Weight and Diet – U.S. – May 2009, Mintel International Group Ltd.

² Mintel International Group Ltd. database search April 2009

³ Satiety and the Consumer, Dairy Management Inc. July 28, 2008

⁴ Tang JE, et al. Minimal whey protein with carbohydrates stimulates muscle protein synthesis following exercise in trained young men. *Appl Physiol Nutr Metab* 2007;32(6):1132-1138.

⁵ Doherty TJ. Invited review: Aging and sarcopenia. *J Appl Physiol* 2003;95:1717-1727.

⁶ Paddon-Jones D, et al. Role of dietary protein in the sarcopenia of aging. *Am J Clin Nutr* 2008;87(5):1562S-1566S.

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Dairy Research Centers Support Product Innovation

Many research findings referenced in this report have been conducted through a collaborative effort by research centers in the National Dairy Foods Research Center Program. Sponsored by Dairy Management Inc.™, this coordinated research program provides the industry with leading-edge dairy product and ingredient research, and technical resources that support dairy industry innovation.

California Dairy Research Center

- California Polytechnic State University (San Luis Obispo)
- University of California – Davis

Midwest Dairy Foods Research Center

- University of Minnesota (St. Paul)
- South Dakota State University (Brookings)
- Iowa State University (Ames)

Southeast Dairy Foods Research Center

- North Carolina State University (Raleigh)
- Mississippi State University (Starkville)

Western Dairy Center

- Utah State University (Logan)

Wisconsin Center for Dairy Research

- University of Wisconsin-Madison

Applications/technology development labs

These labs provide assistance in prototype concept development, product and process troubleshooting, product and process scale up, and sensory evaluation.

Dairy Products Technology Center

- California Polytechnic State University (San Luis Obispo)

Dairy Technology and Innovations Laboratory

- Utah State University (Logan)

Institute for Dairy Ingredients Processing

- South Dakota State University (Brookings)

Sensory Applications Laboratory

- North Carolina State University (Raleigh)

Wisconsin Center for Dairy Research

- University of Wisconsin-Madison ■